

REMARKS

The RCE Transmittal filed concurrently herewith is noted. The present amendments constitute the necessary Submission for this RCE Transmittal.

Also to be noted in this RCE Transmittal is the request for suspension of action on the above-identified application, under 37 CFR 1.103(c), for a period of three (3) months. This request for suspension of action is renewed herein.

Initially, the undersigned thanks the Examiner for the interview conducted on September 25, 2006, in connection with the above-identified application. During this interview, differences between the teachings of the applied prior art and the present invention were discussed, and it was also indicated by the undersigned as to advantages achieved by the present invention due to these differences. In addition, during the interview the evidence of record was discussed; and the presentation of an additional Declaration for establishing unexpectedly better results achieved by the present invention, as compared with the composition of Lee, et al., was discussed. No agreement was reached during this interview.

Applicants have amended their claims in order to further clarify the definition of various aspects of the present invention. Specifically, each of independent claims 62, 65, 69, 89, 93 and 97 has been amended to recite that the polishing medium has a property that a ratio of (a) a polishing rate of a surface having at least one of tantalum, a tantalum alloy and a tantalum compound, or a barrier layer of tantalum, a tantalum alloy or a tantalum compound, which is a barrier layer for a conductor of copper, copper alloy or copper oxide, to (b) a polishing rate of this conductor, using the polishing medium, is greater than 1. Note, for example, previously considered claims 60 and 63. In addition, Applicants are amending claims 65 and 93 to recite that the polishing medium includes abrasive grains. Furthermore, Applicants are

canceling claims 38, 42-49, 54, 55, 59-61, 63 and 85-88 without prejudice or disclaimer.

Moreover, Applicants are adding new claims 101-112 to the application. Claims 101, 102, 104, 106, 107 and 109, dependent respectively on claims 62, 65, 69, 89, 93 and 97, recite that the oxidizing agent is hydrogen peroxide, or that the medium includes hydrogen peroxide. Claims 103, 105, 108 and 110, dependent respectively on claims 65, 69, 93 and 97, recite that the surface is the surface of a barrier layer of tantalum, a tantalum alloy or a tantalum compound, with this barrier layer being a barrier layer for the conductor of copper, copper alloy or copper oxide thereon. Claims 111 and 112, each dependent on claim 62, further defines the ratio of polishing rate of the barrier layer to polishing rate of the conductor, consistent with descriptions in Table 2 on page 32 of Applicants' specification (note, for example, CMP polishing rates set forth in Examples 11 and 13 in Table 2 of Applicants' specification).

In view of present submission of the RCE Transmittal, clearly entry of the present amendments is proper, notwithstanding Finality of the Office Action mailed April 24, 2006.

It is respectfully submitted that all of the claims presented for consideration by the Examiner patentably distinguish over the teachings of the prior art applied by the Examiner in rejecting claims in the Office Action mailed April 24, 2006, that is, the teachings of the U.S. patents to Lee, et al., No. 6,171,352, and to Hardy, et al., No. 6,238,592, under the provisions of 35 USC 103.

It is respectfully submitted that the references as applied by the Examiner would have neither disclosed nor would have suggested such polishing medium as in the present claims, having abrasive grains, with the medium including, inter alia,

an oxidizing agent, a protective-film-forming agent, an acid and water, wherein the polishing medium has a pH of 3 or less and includes the oxidizing agent in a concentration of from 0.01% by weight to 3% by weight, and wherein the polishing medium has a property of polishing a barrier layer of tantalum, a tantalum alloy or a tantalum compound, which is a barrier layer for a conductor of copper, copper alloy or copper oxide, and wherein the polishing medium also has a property that a polishing rate of the barrier layer to the polishing rate of the conductor, in the polishing medium, is greater than 1 (that is, the polishing medium has a selectivity for the polishing of the barrier layer). See claim 62. Note also claim 89, reciting specific materials in the medium. See also claims 103, 105, 108 and 110. Note also claims 111 and 112, further defining the polishing rate ratio.

In addition, it is respectfully submitted that the teachings of the applied references would have neither disclosed nor would have suggested such polishing medium as in the present claims, having the recited components with amount of oxidizing agent of 0.01% by weight to 3% by weight and the medium having a pH of 3 or less, the medium having a property of being capable of chemical-mechanical polishing a surface having at least one of tantalum, a tantalum alloy and a tantalum compound, and also having a property that the polishing rate of this surface using this polishing medium, to the polishing rate of a conductor selected from the group consisting of copper, copper alloy and copper oxide, using this polishing medium, is greater than 1. See claims 65 and 69. Note also claims 93 and 97, reciting specific materials for components of the polishing medium.

Moreover, it is respectfully submitted that the applied references would have neither disclosed nor would have suggested such polishing medium as in the present claims, as discussed previously in connection with claim 62, including abrasive

grains, and wherein the abrasive grains have an average particle diameter of 50 nm or less and the abrasive grains have a standard deviation of particle size distribution in a value of more than 5 nm. See claim 25.

Furthermore, it is respectfully submitted that the applied references would have neither taught nor would have suggested such polishing medium as in the present claims, having features as discussed previously in connection with claim 62, and wherein the medium further includes a water-soluble polymer, with the concentration of oxidizing agent in the polishing medium being in a range of from 0.01% by weight to 1.8 % by weight. Note, for example, claim 27.

In addition, it is respectfully submitted that the teachings of the applied references would have neither disclosed nor would have suggested the polishing medium for chemical-mechanical polishing having components as referred to previously, and having a polishing-rate ratio of specified tantalum-containing material to specified copper-containing material that is greater than 1, and a polishing rate ratio of specified tantalum-containing material to silicon dioxide of more than 10. See claim 51.

Moreover, it is respectfully submitted that the teachings of the applied prior art would have neither disclosed nor would suggested the other aspects of the present invention as in the remaining, dependent claims, being considered on the merits, including (but not limited to) the amount of abrasive grains mixed into the polishing medium, as in, for example, claim 26; and/or wherein the oxidizing agent is included in the polishing medium in a concentration of from 0.01% by weight to 1.5% by weight (note, for example, claim 29; see also claims 68, 72, 92, 96 and 100); and/or wherein the acid of the polishing medium is an organic acid (see, e.g., claim 30), in particular, wherein such acid is at least one selected from the group thereof set forth

in claim 31; and/or wherein the medium includes hydrogen peroxide (see claims 101, 102, 104, 106, 1207 and 109).

Moreover, attention is directed to the Declaration under 37 CFR 1.132 of Mr. Y. Kurata, one of the named inventors in the above-identified application, providing evidence of unexpectedly better results achieved according to the present invention, including ranges of amount of oxidizing agent, and pH of the medium, as in the present claims. This Declaration was submitted with the Submission (Amendment) filed June 6, 2005, and an additional copy was submitted with the Request For Clarification filed September 6, 2005. As discussed infra, it is respectfully submitted that this evidence establishes unexpectedly better results achieved by the present invention, so as to clearly support a conclusion of unobviousness of the presently claimed subject matter. Note Manual of Patent Examining Procedure (MPEP) 2131.03, sub-section II.

The presently claimed invention, as being considered on the merits herein, is directed to a polishing medium, for chemical-mechanical polishing, having abrasive grains.

In metal formation such as in the formation of damascene wirings of copper or copper alloy or the formation of plug wirings of tungsten, a phenomenon called "thinning" in which the thickness of wiring becomes small together with an interlaminar insulating film may occur when an interlaminar insulating film of, e.g., silicon dioxide, is polished at a rate close to the rate of polishing the metal film. As a result, there may be caused an increase in wiring resistance or a non-uniformity in resistance ascribable to pattern density. Hence, it is desired that the polishing medium for chemical-mechanical polishing has a property that the polishing rate of a

silicon dioxide film is sufficiently smaller than that of the metal film to be polished.

Note the last paragraph on page 5 of Applicants' specification.

It is also desired that in performing the metal polishing, "dishing" of the surface of the metal wiring, wherein the surface becomes hollow at the middle thereof like a dish, resulting in a bad effect on flattening, be avoided.

In chemical-mechanical polishing of, e.g., a layer of copper or copper alloy of wiring, together with polishing of, e.g., a layer of tantalum, tantalum alloy, tantalum nitride or other tantalum compound as a barrier layer (tantalum being most commonly used as a barrier metal film), a two-step polishing method has been proposed, having a first step of polishing the copper or copper alloy and a second step of polishing the barrier layer conductor underlying the copper or copper alloy. In this two-step method, and in particular in the second step of polishing the tantalum-containing material, used for the barrier layer, it is important to polish the barrier layer without thinning the silicon dioxide film, and also while avoiding dishing of copper-containing material of the wiring. Note, in particular, the paragraph bridging pages 6 and 7 of Applicants' specification.

Against this background, and as a result of extensive studies performed by the present inventors, the inventors have discovered that the polishing of the tantalum-containing materials proceeds with ease, without undue polishing of the copper-containing conductor or the silicon oxide, when the polishing medium has both a low pH and the oxidizing agent is included in the medium in a low concentration. Thus, according to the present invention, Applicants provide a polishing medium having specified components, including an oxidizing agent and a protective-film-forming agent, wherein the polishing medium has a pH of 3 or less and the oxidizing agent is included in a concentration of from 0.01-3% by weight,

achieving objectives of the present invention of a relatively high polishing rate of the material of the barrier layer, while avoiding dishing and thinning, respectively, of the, e.g., copper wiring and of the oxide insulator, and which additionally can avoid scratches from occurring in the wirings. Thus, as described on pages 8 and 9 of Applicants' original disclosure, the present inventors have discovered that the polishing of the tantalum, tantalum alloy, tantalum nitride and other tantalum compounds which are used as the barrier layer, proceeds with ease in a low pH range and where the oxidizing agent is included in the medium at a low concentration. Moreover, at such low pH and low concentration of the oxidizing agent, etching rate of copper or copper alloy does not increase, avoiding dishing problems.

More specifically, as described in the sole full paragraph on page 16 of Applicants' specification, in general when the polishing medium has a pH of less than 3, etching rate of the copper or copper alloy film is so high as to make it difficult for the protective-film-forming agent to control the etching. However, in the present invention, the concentration of the oxidizing agent is so sufficiently low that the protection-film-forming agent can control the etching.

The results of selective polishing of the tantalum-containing material, with respect to the conductor of copper-containing material, is particularly surprising in light of the relative softness of the copper-containing materials to the relatively hard tantalum-containing materials. That is, as can be appreciated, tantalum-containing materials are relatively harder than the copper-containing materials, and it would have been expected that polishing of copper-containing materials would proceed at a higher rate than the polishing of the tantalum-containing material. To the contrary, and with use of the polishing medium as in the present claims, including wherein

such polishing medium has a pH of 3 or less and a relatively low amount of oxidizing agent (a concentration of from 0.01% by weight to 3% by weight), it has been unexpectedly found that this composition has selectivity for the polishing rate of the tantalum-containing compound as compared to polishing rate for the copper-containing compound, providing advantages achieved by the present invention including, for example, decreased dishing of the copper-containing material conductor.

Furthermore, by utilizing abrasive grains having an average particle diameter as in various of the present claims, the polishing rate of silicon dioxide is decreased, avoiding any "thinning" problems. See the paragraph bridging pages 21 and 22 of Applicants' specification.

As for unexpectedly better results achieved according to the present invention, attention is respectfully directed to the aforementioned Declaration under 37 CFR 1.132, and in particular the Experiments described therein and experimental results set forth therein.

As seen in Additional Experiment 1 on pages 1-4 of the Declaration, Chemical A, within the scope of the present invention, achieved a high removal rate of tantalum nitride and tantalum as compared to the removal rate of copper and silicon oxide, while Chemicals B and C, outside the scope of the present invention, had higher rates of polishing of copper and also had relatively low polishing rates of the tantalum-containing materials. Additional Experiment 2 on pages 5 and 6 of the Declaration shows that with use of a polishing medium according to the present invention, including abrasive grains, the removal rate increased with decrease of abrasive size, which is unexpected (removal rate increasing with increased abrasive size using chemicals outside the scope of the present claims, or in removing silicon

oxide using Chemical A within the scope of the present claims or Chemical B outside the scope of the present invention).

In Additional Experiment 3 on pages 7 and 8 of the Declaration, it can be seen that a high removal rate of tantalum nitride and tantalum, as well as improved selectivity of removing tantalum-containing compounds as compared with copper, is achieved at relatively low pH within the scope of the present claims. Additional Experiment 4 on pages 9 and 10 of the Declaration shows that at relatively low oxidizing agent concentration (a concentration of less than 3% by weight), polishing rate of tantalum and tantalum nitride are relatively high, as compared with concentrations over 3% by weight; and selectivity for removal of tantalum-containing compounds as compared with polishing of copper can be achieved at relatively low oxidizing agent concentration.

Additional Experiment 5 on pages 11 and 12 of the Declaration shows that with polishing media containing a water-soluble polymer (polyacrylic acid ammonium salt), decreased oxidizing agent concentration achieves increased removal of tantalum-containing materials, contrary to expectation; and, moreover, at low oxidizing agent concentration, a selectivity for removal of tantalum-containing material relative to removal of copper can be achieved. Additional Experiment 6 on pages 13 and 14 of the Declaration shows that decrease of pH can achieve a high polishing speed for tantalum and tantalum nitride materials, which is the opposite result achieved in connection with copper and titanium nitride films. That is, as seen in Additional Experiment 6, polishing speeds of the copper film and the titanium nitride film show behaviors completely different from that of the tantalum-containing film.

It is respectfully submitted that these Additional Experiments 1-6 show unexpectedly better results with respect to polishing of tantalum-containing materials, for polishing media as in the present claims having a relatively low pH and a relatively small amount of oxidizing agent, supporting unobviousness of the presently claimed invention.

In Items 5 and 6 on page 5 of the Office Action mailed April 24, 2006, the Examiner contends that the Declaration under 37 CFR 1.132 is not persuasive, because it does not compare the claimed subject matter with the closest prior art, and that it refers only to the "system" described in the present application and not to individual claims of the application. It is respectfully submitted, however, that the Declaration provides comparative evidence with respect to media closer to the present invention than the closest prior art, and thus constitutes a proper test for establishing unobviousness. While the Examiner contends that the Declaration refers only to the "system" (as clarified during the above-mentioned interview, such "system" as referred to by the Examiner is the description in the specification), it is respectfully submitted that the test data in the Declaration provides evidence with respect to the claims of the above-identified application, establishing unexpectedly better results in connection therewith.

The additional contention by the Examiner in Item 6 on page 5 of the Office Action mailed April 24, 2006, that the examples in the Declaration show the composition having abrasive grains while some of the independent claims recite the composition having no abrasive grains, is noted. All of the presently submitted claims recite inclusion of abrasive grains, so that this contention by the Examiner is moot with respect to claims presently in the application.

Lee, et al. discloses a chemical-mechanical abrasive composition for semiconductor processing, which includes 70-95% by weight of an aqueous medium, 1-25% by weight of an abrasive and 0.1-20% by weight of an abrasion accelerator, the abrasion accelerator including a monocarboxy group- or an amido group-containing compound and optionally a nitrate salt. See column 2, lines 38-48. This patent goes on to disclose that the abrasive composition can further include 1-15% by weight of, and preferably 4-8% by weight of, an oxidant. See column 2, lines 63-65. Note also column 3, lines 3-7 for specific oxidants. This patent further discloses that when used in a copper production process, the abrasive composition may include benzotriazole and/or its derivatives to inhibit rapid copper corrosion. See column 4, lines 13-20. Note also column 4, lines 30-40, for a disclosure of adjustment of the pH, with respect to polishing various materials. These various materials include copper and tungsten, but do not include tantalum, tantalum alloys or tantalum compounds. Note also specific compositions in the Examples.

In column 6, lines 56-62, Lee, et al. discloses that in the process for producing integrated circuits, Ta is most commonly used as a barrier metal film; and that, nevertheless, since Ta has a high chemical resistance, achieving effective polishing of Ta is usually difficult. This patent goes on to describe that it has been found that the abrasive composition disclosed therein is able to provide excellent polishing efficacy for Ta, as illustrated in, for example, Examples 4-8 in Lee, et al. Examples 4-8 refer to preparation steps of Example 1 in Lee, et al.; Example 1 of Lee, et al. describes adjustment of the slurry to have a pH of about 3.8. See column 4, lines 62 and 63 of Lee, et al.

It is respectfully submitted that Lee, et al. would have neither taught nor would have suggested the combination of relatively low pH and relatively low amount of

oxidizing agent, and advantages thereof, e.g., in polishing tantalum-containing with selectivity relative to polishing copper-containing materials and/or silicon oxide.

Note that the Examples in Lee, et al. disclose adjustment of the pH of the slurry to have a pH of about 3.8 in Example 1, and to have a pH of about 2.2 (in Example 3). Comparative Example 1 of Lee, et al. also discloses adjustment of the pH to have a pH of about 2.2. Moreover, Lee, et al. discloses that polishing tantalum is difficult. See, for example, column 6, lines 56-61 of Lee, et al. But note, also, Table 3 in column A of Lee, et al. Taking the teachings of Lee, et al. as a whole, it is respectfully submitted that such teachings do not disclose, nor would have suggested, advantages achieved as in the present invention, using a relatively low concentration of oxidizing agent and relatively low pH.

Moreover, note that Table 3 of Lee, et al., which shows tantalum removal rate, shows such removal rate in connection with Examples 4-8 and Comparative Example 2. However, note that Examples 4-8 refer to the same preparation steps as in Example 1, in which the slurry was adjusted to have a pH of about 3.8. It is respectfully submitted that Lee, et al., either alone or in combination with the teachings of the other applied reference, would have neither disclosed nor would have suggested such pH as in the present claims for polishing of tantalum, much less the combination of pH and oxidizing agent concentration as in the present claims and advantages thereof for selective polishing of tantalum-containing material as compared to polishing of copper-containing material.

It is respectfully submitted that the teachings of the secondary reference as applied by the Examiner, Hardy, et al., would have not have rectified the deficiencies of Lee, et al. such that the presently claimed invention as a whole would have been obvious to one of ordinary skill in the art.

Hardy, et al. discloses a family of working liquids useful in modifying exposed intermediate surfaces of structured wafers for semiconductor fabrication, the working liquid being a solution of initial components comprising an oxidizing agent; an ionic buffer; a passivating agent; a chelating agent selected from iminodiacetic acid and salts thereof; and water. This patent discloses that the passivating agent may be an azole derivative preferably selected from benzotriazole, tolyltriazole or combinations thereof. See column 3, lines 40-45. See also column 7, lines 19-30; and column 7, line 64 to column 8, line 2. Note also column 9, lines 30-33; and column 9, line 67 to column 10, line 3, disclosing that the average particle size of inorganic particulates, included in the working liquid to increase removal rate of the metal and/or dielectric, to be less than about 1000 Angstroms. See also, column 10, line 9, disclosing amount of the inorganic particulates in the working liquid.

Even assuming, arguendo, that the teachings of Hardy, et al., were properly combinable with the teachings of Lee, et al., it is respectfully submitted that these combined teachings would have neither disclosed nor would have suggested such polishing medium as in the present claims, having pH and concentration of oxidizing agent, and having size of the abrasive which achieves advantages according to the present invention as discussed previously, and, as shown e.g., in Additional Experiment 2 in the aforementioned Declaration submitted in the above-identified application.

The contention by the Examiner in the paragraph bridging pages 2 and 3 of the Office Action mailed April 24, 2006, that oxidizing agent concentration and pH are result-effective variables because Lee, et al. shows there are concentration and pH ranges; and that, therefore, it would have been obvious for one skilled in the art to determine the oxidizing concentration and pH through routine experimentation to

provide an optimum concentration and pH for the polishing composition depending of the material being polished, is respectfully traversed. While Lee, et al. may disclose oxidizing agent concentration and pH, it is respectfully submitted that this patent does not teach, nor would have suggested, such parameters are "result-effective" variables, especially in combination, as described in connection with the present invention; much less that these parameters would effect selectivity as discussed previously. It is respectfully submitted that Lee, et al. does not disclose, nor would have suggested, modifying combination of pH and oxidizing agent concentration, as in the present claims, and advantages achieved thereby.

Moreover, it is respectfully submitted that the Declaration previously submitted, as well as disclosure in Applicants' original Specification and examples therein, show unexpectedly better results achieved according to the present invention, with pH and oxidizing agent concentration as in the present claims.

It is respectfully submitted that this evidence of unexpectedly better results overcomes any possible *prima facie* case of obviousness established by the Examiner, clearly establishing unobviousness of the claimed subject matter.

The contention by the Examiner that the composition of Lee, et al. would have the polishing rate ratio between different materials recited in the present claims, the Examiner contending that the composition includes the same compounds with the same concentrations as that of the present claims, set forth in the third full paragraph on page 3 of the Office Action mailed April 24, 2006, is noted. While there is overlap between various concentrations/pH, it is respectfully submitted that the Examiner has not established that compositions as in Lee, et al., would always (that is, inherently) have the polishing-rate ratio as in the present claims, or advantages achieved thereby.

The Examiner contends in Item 4, in the paragraph bridging pages 4 and 5 of the Office Action mailed April 24, 2006, that the fact that Applicants have recognized another advantage which would flow naturally from following the suggestion of the prior art, cannot be the basis for patentability "when the differences would otherwise be obvious". It is respectfully submitted, however, that the Examiner has not established a basis for modification of the teachings of Lee, et al., to provide the combination of features (e.g., pH of 3 or less and oxidizing agent concentration of from 0.01% by weight to 3% by weight) providing the advantages achieved by the present invention. The Examiner has indicated no motivation, from the teachings of the applied references, for choosing from among the wide range of pH and wide range of oxidizing agent concentration in Lee, et al., as well as the large number of materials forming the composition in Lee, et al., for choosing the presently claimed subject matter. Particularly in view of advantages achieved by the present invention, as discussed previously and as shown by the evidence of record, it is respectfully submitted that the Examiner has not shown that Applicants have merely recognized another advantage which would flow naturally from following the suggestion of the prior art.

Again, Applicants note their request for a suspension of action for three (3) months in the above-identified application, and respectfully request that the Examiner wait to take up the above-identified application for examination until after the end of such suspension, for full consideration of the presently amended claims in light of, inter alia, all evidence of record in the application.

In any event, upon full consideration of the above-identified application, after the end of the aforementioned suspension period, allowance of all claims in the application is respectfully requested.

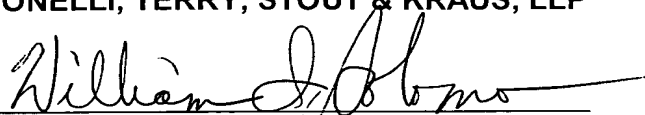
October 23, 2006

To the extent necessary, Applicants petition for an extension of time under 37 CFR 1.136. Please charge any shortage in fees due in connection with the filing of this paper, including extension of time fees, to the Deposit Account of Antonelli, Terry, Stout & Kraus, LLP, Deposit Account No. 01-2135 (case No. 1204.41191X00) and please credit any excess fees to such Deposit Account.

Respectfully submitted,

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